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13. ABSTRACT (Maximum 200 words) Matter wave interferometers, in which atomic or molecular de Broglie waves are coherently split and then recombined to produce interference fringes, have opened up exciting new possibilities for precision and fundamental measurements with complex particles. The MIT interferometer in particular is the only demonstrated atom interferometer that spatially separates the two parts of the matter waves in a way that allows the insertion of a barrier between them before they are recombined. The aim of our research program is to take advantage of this ability to accurately measure interactions that displace the de Broglie wave phase in order to make qualitatively new and precise measurements in atomic and molecular physics, to devise new techniques for measuring acceleration and rotation, and to perform fundamental tests of quantum mechanics. In addition, we are continuing to develop new atom optical methods such as a new laser-grated velocity selection technique to improve the precision of future interferometric measurements and the use of time dependent beam splitters to probe longitudinal coherences in atom beams. As an integral part of our program, we are also continuing to develop new atomic physics tools such as smaller period gratings for wider separation of atom beams and precision interaction regions using nanotechnology and micromachining.				
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Atom Interferometry Annual Progress Report
12/1/95-11/30/96
David E. Pritchard-MIT

1. Research Objective

Matter wave interferometers, in which atomic or molecular de Broglie waves are coherently split and then recombined to produce interference fringes, have opened up exciting new possibilities for precision and fundamental measurements with complex particles. The MIT interferometer in particular is the only demonstrated atom interferometer that spatially separates the two parts of the matter waves in a way that allows the insertion of a barrier between them before they are recombined. The aim of our research program is to take advantage of this ability to accurately measure interactions that displace the de Broglie wave phase in order to make qualitatively new and precise measurements in atomic and molecular physics, to devise new techniques for measuring acceleration and rotation, and to perform fundamental tests of quantum mechanics. In addition, we are continuing to develop new atom optical methods such as a new laser-grated velocity selection technique to improve the precision of future interferometric measurements and the use of time dependent beam splitters to probe longitudinal coherences in atom beams. As an integral part of our program, we are also continuing to develop new atomic physics tools such as smaller period gratings for wider separation of atom beams and precision interaction regions using nanotechnology and micromachining.

2. Progress

Atom interferometers are extremely sensitive to rotations. By suspending our interferometer and subjecting it to a slow sinusoidal rotational oscillation, we have observed rotation rates down to 50 milli-earthrates in a 20 s measurement (the noise in a one second measurement is 40 milli-earthrates) and have shown the response to have better than 1% agreement with theory. This sensitivity is comparable to the best commercially available laser gyros. A dedicated instrument using Cs atoms instead of Na and designed around projected 1 cm square gratings should have a sensitivity that is four orders of magnitude better, making its performance superior to the best technologies in current use.

Over the past year, we have also taken key steps towards improving the sensitivity of our atom interferometer in preparation for precision measurements. In collaboration with the Nanostructures Laboratory at Cornell University, we have successfully microfabricated 200, 160 and 140 nm period diffraction gratings. Atomic interference has been observed using these gratings, and also with 100 nm gratings fabricated in the Nanostructures Lab of Hank Smith here at MIT. The finer gratings will allow us to explore higher beam velocities during studies of interatomic potential dispersion (see below). Finally, using micromechanical fabrication techniques, we have constructed an atom interaction cell with an exceptionally thin (10 μm) silicon wall, thus facilitating the cell's placement in one of the interferometer's physically separated beam paths.

3. Future Plans

We are currently rebuilding the interferometer, making it longer and more sensitive. The new design also incorporates an improved inertial isolation system (important because random rotational and vibrational noise reduce the contrast in our current interferometer), modularity to facilitate a variety of experiments, and flexibility to multitask experiments.

Upon completion of the rebuild, we will pursue an experiment using the MIT interferometer's unique sensitivity to interaction induced phase shifts to study the velocity dependence of atom-atom potentials. There is significant interest in the theoretical community in such experiments as they probe the long range behavior of atomic potentials, which are important for Bose-Einstein condensation for example. It is anticipated that the index of refraction should exhibit Glory oscillations as the velocity of the impinging gas is increased.

In addition, we propose to investigate the fundamental question as to the extent to which various longitudinal momentum states are correlated in an atom beam. By incorporating Ramsey separated oscillatory fields into our interferometer and by using them to provide momentum kicks, we have figured out a way to overcome any degradation of the momentum correlation due to velocity averaging. Preparations for this experiment are currently underway.

Other experiments being planned include investigation of the Aharonov-Casher effect, measurement of Berry's phase for massive bosons, search for extremely small interactions such as the controversial Anandan force, and tests of the robustness of interference (such as the persistence of atomic interference fringes despite the atom's spontaneous emission of photons in the interferometer).

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